Thermal Gaping and Ejectability of Meat from the Pacific Oyster

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ABSTRACT

Whyte, J.N.C. and B.L. Carswell. 1984. Thermal gaping and ejectability of meat from the Pacific oyster. Can. Tech. Rep. Fish. Aquat. Sci. 1283: v + 19 p.

Oysters from bottom, string or French-tube cultures were subjected to atmospheric steam, pressurized steam and microwave energy to assess effectiveness of thermal gaping and shell-adductor muscle separation allowing for ejectable cooked body meat. Prolonged treatment with atmospheric steam was required to provide a high percentage of gaped oysters with ejectable body meat. Microwave energy was efficient at providing ejectable body meat only when oyster fluids were contained. These process constraints would adversely affect the economic commercial viability of an automated shucking system. Pressurized steam at 110°C for 5 to 10 minutes efficiently provided gaped and ejectable oysters which had lost tissue fluid to provide firm-textured meat suitable for mechanical meat-shell separation and further processing.

Key words: oyster Crassostrea gigas, oyster gaping with thermal energy, oyster meat ejectability, oyster shucking.

RÉSUMÉ

Whyte, J.N.C. et B.L. Carswell. 1984. Ecartement thermique et éjectabilité de la chair de l'huître du Pacifique. Can. Tech. Rep. Fish. Aquat. Sci. 1283: v + 19 p.

Des huîtres provenant de cultures de fonds, sur cordes ou en tubes (French-tube cultures) furent soumises à la vapeur atmosphérique, la vapeur sous pression et l'énergie à micro-ondes pour évaluer l'efficacité de l'écartement thermique et de la séparation du muscle abducteur des écailles afin de permettre l'éjection de la chair cuite. Il fallut un traitement prolongé à la vapeur atmosphérique pour obtenir un pourcentage élevé d'huîtres ouvertes à chair éjectable. L'énergie à micro-ondes était efficace pour rendre la chair éjectable uniquement lorsque les huîtres gardaient encore leur liquide. Ces limitations du procédé influenceraient de façon adverse l'utilité commerciale d'un système automatique d'ouverture d'huîtres. Un traitement de 5 à 10 minutes à la vapeur sous pression à 110°C produisait de façon efficace des huîtres ouvertes à chair éjectable, qui ayant perdu leur liquide avaient une texture ferme, propice à la séparation mécanique des écailles et aux traitements ultérieurs.

Mots clefs: l'huître, Crassostrea gigas, moyen thermique pour ouvrir l'huître, l'éjectabilité de la chair d'huître, l'écartement des écailles d'huître.

INTRODUCTION

Hand shucking of oysters with an oyster knife is difficult, tedious and potentially hazardous from shell lacerations. Escalating labour costs combined with a decline in personnel willing to undertake this type of employment has prompted research into alternate methods for removing meat from oysters.

Over the past 50 years inventions such as punches or cutting blades to notch the shells for easier insertion of the shucking knife (Dickerson, 1948; Thomson, 1976), uses of wedges to lever apart the valves (Robinson, 1932; Ruiz, 1983) and application of scissor or cleaver type implements (Palmere, 1957; Loubeyre, 1981) have been patented with varied degrees of success.

Patents have been issued for a variety of automated mechanical shuckers working on the principle of gaping by mechanical shock or thermal treatment followed by cutting, shearing, vibrating or tumbling devices to separate the meat from shells. Equipment involving trimming-cutting blades (Fowler, 1973), free-fall impact followed by cutting and tumbling (Harris, 1958), freezing then impact and vibration (Lapeyre et al., 1961), impact by hurling against a stationary plate (Cohen, 1980) shell-shearing (Cox, 1981) and rapid decompression (Comparetto, 1982) are some of the patented mechanical procedures. The complexity of many of these mechanical shucking systems combined with the irregular, clustered and deeply scalloped shells of the Pacific oyster suggests that prospects for development of an economically feasible machine of these types for use in British Columbia are far from encouraging.

Thermal systems to shuck molluscs have included, steaming and tumbling (Carlson, 1979), steaming and vibrating (Lambert, 1981), electric-furnace heating and shaking (Paparella, 1976), infrared heating (Ouw and Johnson, 1973), infrared heating and wedging device (Wheaton and Story, 1974), oxy-acetylene burners (Henry, 1971), microwave radiation (Spracklin, 1971; Mendelsohn et al., 1969), laser beams (Singh, 1972), and steam-shock (Brown, 1982). Application of chemicals to promote shucking has also been patented (Welcker and Welcker, 1961).

Pacific Northwest Laboratories in 1971 tested a diverse number of techniques, other than steam, to promote gaping and concluded, Table 1, that cryogenic freezing with liquid nitrogen and subsequent thawing was effective

in separation of meat from shells, however, the quality of meat was impaired, and that application of specific chemicals was also effective but required further study (Smith, 1971). Effectiveness of a variety of inorganic elements to promote gaping of oysters indicated that magnesium salts were unique in this regard, Table 2, and that on treatment of oysters with this element substantial productivity gains in hand-shucking would result (Whyte and Carswell, 1983).

Although thermal treatment of oysters is known to cause gaping, the degree to which adductor muscle and shell separate and the ease of ejection of the resultant body meat through the shell opening are crucial to the efficiency of an automated shucking system. Recognizably these factors are influenced by the physical condition of the oyster and the shape, thickness and clustered arrangement of the shells surrounding the body. The effectiveness of atmospheric steam, pressurized steam, and microwave energy to overcome these factors in producing shucked, cooked oysters suitable for further processing is presented in this report.

MATERIAL AND METHODS

Laboratory tested molluscs were obtained as bottom oysters from Okeover, as string oysters from Allies Island, or as French tube grown oysters from Tofino, which were all acclimated to the irrigant seawater in holding facilities at the West Vancouver Laboratory. Treatment of oysters to atmospheric steam was performed by placing the animals in a 2-tiered aluminum steamer (50 cm diam.) and maintaining water in the bowl at a rolling boil. Treatment with pressurized steam was conducted in a canning retort (285 L) fed with steam at 15 p.s.i. and controlled by in-line valves from Taylor Instrument Companies. Treatment with microwave energy (600 W at 2450 MHz) was conducted in a Panasonic microwave oven. Five to twenty oysters were used for each trial with results presented from averaged duplicate or triplicate runs. Oysters gaped and body meat ejected from these were counted to provide percentage gaped and of these the percentage ejectable. Ejectable and shucked non-ejectable meats were combined and weighed to yield meat recovered as a percentage of total weight of oysters treated.

RESULTS AND DISCUSSION

Application of heat to oysters caused varying degrees of gaping, however, not all gaped oysters released resultant body meat when shaken. This resulted from adductor muscle attachment to one or both shells or lack of sufficient gaping of the shells to allow escape of totally detached body meat. The latter condition resulted from shell growth, or neighbouring shell in a clustered arrangement restricting the pivoting action at the hinge ligament. Ejectability of the body meat was determined by gently shaking the oyster in an anterior-posterior direction holding the shells at the anterior (hinged) end, Fig. 1. This directional action allowed for maximum displacement of detached meat whereas shaking in a dorsal-ventral direction diminished meat escapement because of reduced opening towards the anterior (hinged) end. Body meat ejectable is given as a percentage of total animals gaped.

Although 50 to 100% of the bottom oysters gaped on treatment with atmospheric steam for intervals up to 60 min., only a maximum of 60% of the body meat was ejectable on shaking and half of these retained smooth muscle attachment to one or both shells and failed to emerge cleanly, Table 3. Steaming for 90 to 180 min. tended to produce more ejectable meat but from the percentage meat recovery in the cooked oysters this meat suffered dehydration from the prolonged heating. The range in percentage gaping with time, evident in Table 3, illustrated the varying reaction to heat by the test animals. Lower percentage gaped and meat ejectable from the oyster steamed for 120 min. relative to those for 90 and 180 min. reflected presumably the slightly larger size class.

Larger oysters grown on French-tubes when heated with atmospheric steam presented results similar to those from bottom oysters. From 90-100% gaped after 120 min. but only 80% of the body meat was ejectable after prolonged 180 min. cooking, Table 4. This prolonged cooking resulted in loss of oyster meat weight by dehydration. Total weight loss of whole French-tube oysters on cooking with atmospheric steam for 30 to 120 min. ranged randomly from 14.8 to 18.4% indicating the differential inclusion of fluid trapped between the valves prior to heating, Table 5. Atmospheric steam as an aid to shucking oysters required extensive reaction times which would decrease the economic viability of the process.

Bottom oysters placed in a microwave oven were only 60% gaped in 10 min. and of these only 66.7% were ejectable, Table 6. Only 20% of the larger string oysters had gaped when treated with 600 watts of energy for the same time and none were ejectable. A further 5 min. of radiation was required to produce a 60% gaping rate of which only a third were ejectable, but during this additional cooking a 3.3% decline in meat recovery resulted, Table 6. Observed low gaping and ejectability rates were considered to result from the nature of microwave heating. Radiant energy vaporized water rapidly within the shell cavity and as vented steam allowed for baking of the meat to the inside of the dry shells. In addition almost instantaneous denaturation of muscles in the adductor inhibited relaxation and gaping. Extent of gaping under microwave heating would therefore depend on content and retention of fluid within the shell cavity. Retention of this fluid during microwave heating was accomplished by sealing the oysters in plastic boiling pouches. Under these conditions 80-100% gaped and were ejectable in 5 to 7 min., Table 7. Continued heating beyond this time frame caused evident dehydration of the meat and fewer ejectable oysters caused by attachment of meat to dry shell. These results indicated that use of microwave energy in shucking oysters was only feasible when contained in an enclosed area to prevent rapid moisture loss, which would reduce the economic viability of such a process.

Treatment of bottom oysters with pressurized steam at 110°C (230°F) in a canning retort was 100% effective in gaping and ejecting body meat after 15 or 30 min., Table 8, however about 20% of the ejected oysters were not fully detached and residual muscle remained with the shells. Increasing the temperature by 5.6°C (10°F) appeared to have a slight adverse effect on recovery of ejectable oysters but as no significant dehydration was evident from the percentage of meat recovered the anomaly was considered a factor of biological variance.

To determine if spatial restrictions would affect gaping or ejectability, bottom oysters were stacked singly or from nine to ten deep and subjected to pressurized steam at 110°C. Results obtained, Table 9, indicated a reduction in ejectable oysters when stacked together although the gaping rate was comparable, suggesting full opening of the shells may have been prevented by spatial hindrance. Under both conditions only about 50% of the oysters were ejected cleanly as a result of slight attachment of adductor muscles. This probably could be eliminated by using higher pressure steam, which was

unavailable for these trials.

Total weight loss incurred in steaming bottom oysters with atmospheric or pressurized steam was 10.9 and 15.8% respectively illustrating the additional loss in tissue water at the higher reaction temperature, Table 10. This was corroborated by the observed reduction in meat recovery from 15.6% using atmospheric steam to 12.3% with pressurized steam. Content of the shell cavities was assessed from the weights of the fresh oyster less the shells after cooking and as the theoretical weight of fresh meat allowed for calculation of the theoretical meat loss as 47.5% and 63.1% for the atmospheric and pressurized steam treatment respectively, Table 10. As fluids are always present in the shell cavities of oysters these losses for "meat" were not actual values, however, the significant differential loss from the two distinct shucking conditions was factually evident.

Shorter duration treatment of bottom oysters with pressurized steam indicated a minimum reaction time of 5 min. for efficient gaping and ejectability, Table 11. Triplicate results were not averaged in this Table to illustrate the fluctuation between runs reflecting the natural biological variance in any batch of oysters, which would exist in a commercial operation. A mathematical model has been developed which relates temperature to approximate exposure time required for detachment of oyster meat from shells (Wheaton, 1974):

$$\log_n E = 10.43 - 1.14 \log_n T$$

where E = exposure time in seconds

T = temperature in deg. Celcius

Insertion of 110°C into this equation provided an exposure time of 2.66 min. for shucking oysters, a value slightly more than half the exposure time of 5 min. indicated in results from Table 11. This discrepancy presumably arises from the inserted temperature being lower than the range 120 to 490°C used to generate the equation, with the higher temperatures minimizing time of temperature equilibration which is a function of shell thickness.

Oysters air-stored for 24 hours or longer were more susceptible to gaping from treatment with magnesium chloride (Whyte and Carswell, 1983). Was air-storage also a factor in steam shucking? Bottom oysters held at 5°C in air for up to 3 days were subjected to steam at 110°C for 3 min. This

reaction time deviated from the proposed 5 min. optimum, but made more apparent any incremental changes. Results clearly indicated pre-storage of oysters prior to cooking allowed for significant increases in both gaping and ejectability rates, Table 12. A comparison of percentages of meat in cooked oysters, and theoretical "meat" loss from specimens stored 24, 48 and 72 hours at 5°C, indicated no significant variation in loss of moisture between these stored samples after cooking, Table 12. These data suggested apparent shucking benefits would accrue from pre-storage of oysters prior to steam treatment.

Apparent inconsistencies, in the rates of gaping and ejectability, and subsequent meat recovery recorded within and between trials, were considered to result from biological variance of the test oysters. This was corroborated by the significant variability observed in physical characteristics of bottom oysters selected at random from the oyster stock used for these thermal shucking experiments, Table 13.

In summary, oyster shucking with atmospheric steam required cooking times of the order 120 to 180 min. which would adversely affect the economic viability of this system. From results presented microwave energy was considered an ineffective procedure for thermal shucking of oysters unless special provisions were made to contain oyster fluids. This contrasted with the microwave shucking results of Mendelsohn et al. (1969) but was in complete accord with the negative conclusions to microwave energy presented by Smith (1971) in a similar study. Shucking of oysters with pressurized steam at 110°C for 5 to 10 min. depending on stacking density would provide a high percentage of gaped and ejectable oysters. It should be recognized, however, that the ejectable rates presented in this report were based on meat ejection using a uni-directional shaking hand-action considered unlikely to be fully duplicated with a tumbling or vibrating mechanical system. Thus, although pressurized steam can yield the firm-textured oyster meat essential for further processing (Tanikawa, 1971), the development of a mechanical system for effective and efficient separation of cooked meat which is undamaged and free from shell fragments is paramount to the economic viability of an automated oyster shucking system.

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Table 1. Techniques applied to promote gaping of oysters and aid hand shucking.

Method	Parameters	Observations
Liquid nitrogen cryogenic freezing then thawing	-196°C; 82-139 secs. immersion 20-55°C thawing.	Bond of both hinge and adductor muscle broken; considerable bleeding of meat and texture degradation; 8g LN2/1g meat $6.91/gallon.
Ultrasonic energy	50-400 watts of transducer energy; 5-30 min. duration.	No effect.
Mechanical vibration	Pneumatic hammer at 10, 20 and 30 cps frequency; 30-180 min. duration.	No effect.
Electric shock	0-5000 volts; 0-0.02 amps.	No effect.
Explosive decompression	200-1500 psi in water or air for 15 min. before decompression.	No effect.
Vacuum	10-29 in. Hg vacuum for 30-120 min.	No effect.
Vacuum with ultrasonic pretreatment	10-20 min. of 400 watts 29 in. Hg vacuum.	No effect.
Local heating	Propane and oxyacetylene torch applied to point where adductor attached to shell.	Cooked or burned, no gaping.
Microwave heating	2450 MHz, 15-60 secs.	Cooked or exploded.
Carbon dioxide	Saturated solution for 64 hrs.	No effect.
Anesthetic agents	Ether, chloroform vapours; Chlorodane, MS-222 and Quinaldine as aqueous solutions.	No effect or inconclusive. " "
Chemical treatment	Enzyme papain EDTA Aqueous magnesium chloride.	No effect. " " Effective gaping.

Table 2. Effect of various chemicals on the oyster, Crassostrea gigas.

Chemical	Max. tolerable conc. examined	Exposure time (h) (% survival)	Narcotic effect on adductor muscle	Observations
Acetylene	saturated, 20°C	24 (100)	none	Valves tightly closed.
Carbon monoxide	saturated, 20°C	24 (100)	moderate	Slows contraction of adductor muscle.
Carbon dioxide	saturated, 20°C	24 (100)	none	Normal valve activity.
Nitrous oxide	saturated, 20°C	24 (100)	none	Normal valve activity.
Potassium chloride	1g/L	72 (100)	none	Normal valve activity for 48h; then shut tightly.
Potassium iodide	1g/L	72 (100)	none	Normal valve activity for 48h; then shut tightly.
Calcium chloride (dihydrate)	5g/L	72 (100)	none	Normal valve activity.
Lithium carbonate	0.1g/L	72 (100)	none	Normal valve activity for 48 hr; then shut tightly.
Sodium metabisulphite	0.1g/L	72 (100)	none	Normal valve activity.
Magnesium chloride (hexahydrate)	66.4g/L	24 (100)	strong	Oysters unable to contract after prolonged exposure.
Magnesium sulphate (heptahydrate)	123.2g/L	24 (100)	strong	As above.
Ammonium ferric citrate	0.2g/L	72 (100)	none	Normal valve activity.
Sodium lauryl sulphate	0.1g/L	72 (0)	none	Tissue disintegration very evident. Detergent very insol. in seawater.

Table 3. Effect of treatment of bottom oysters with atmospheric steam.

Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
				Length	Width	Depth
10	60	33.3	14.1	11.2 (1.2)	7.1 (1.0)	4.1 (0.5)
15	50	60.0	14.6	12.0 (1.6)	7.1 (0.5)	4.1 (0.5)
20	100	30.0	11.6	11.4 (0.6)	7.1 (0.5)	4.4 (0.7)
45	60	33.3	11.3	11.6 (1.5)	6.9 (0.6)	3.6 (0.6)
60	50	60.0	10.3	11.5 (1.1)	6.9 (0.9)	3.8 (0.5)
90	80	100.0	13.4	11.7 (1.0)	6.7 (0.4)	3.8 (0.5)
120	70	57.0	11.2	12.0 (1.4)	7.1 (0.8)	4.2 (0.6)
180	100	90.0	9.2	11.7 (1.0)	7.1 (1.6)	4.1 (0.9)

* Values in parentheses are standard deviations.

∓ From cooked ejectable and non-ejectable oysters.

Table 4. Effect of treatment of oysters (French tube) with atmospheric steam.

Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
				Length	Width	Depth
120	90	44.4	15.3	12.0 (1.2)	6.7 (0.7)	4.0 (0.7)
180	100	80.0	11.3	12.4 (1.4)	5.5 (0.9)	3.9 (0.6)

* Values in parentheses are standard deviations.
∓ From cooked ejectable and non-ejectable oysters.

Table 5. Overall loss in oysters (French tube) on treatment with atmospheric steam.

Time (min)	Fresh weight (g)	Cooked weight (g)	Total weight loss (%)	Mean Dimensions (cm)*		
				Length	Width	Depth
30	767.2	642.1	16.31	11.0 (0.9)	6.3 (1.3)	3.5 (0.6)
60	724.2	590.9	18.41	11.2 (1.2)	6.0 (0.5)	3.7 (0.6)
90	615.3	524.0	14.84	10.1 (1.9)	5.7 (0.8)	3.5 (0.5)
120	741.5	625.2	15.68	11.5 (0.9)	6.0 (0.7)	3.3 (0.7)

* Values in parentheses are standard deviations.

Table 6. Effect of treatment of unenclosed oysters with microwave energy.

Type	Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
					Length	Width	Depth
Bottom	10	60	66.7	14.1	12.0 (1.2)	6.8 (0.9)	4.1 (0.3)
String	10	20	0.0	14.0	13.4 (2.3)	7.7 (0.7)	4.9 (0.6)
String	15	60	33.3	10.7	14.1 (1.9)	8.0 (1.2)	4.1 (0.4)

* Values in parentheses are standard deviations.
∓ From cooked ejectable and non-ejectable oysters.

Table 7. Effect of treatment of bottom oysters in sealed pouches with microwave energy.

Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
				Length	Width	Depth
5	80	100.0	14.7	12.1 (2.4)	7.0 (1.0)	3.6 (0.2)
6	100	100.0	15.2	10.9 (1.8)	6.9 (0.7)	4.3 (0.5)
7	80	100.0	13.0	12.3 (1.5)	7.3 (0.9)	4.1 (0.6)
9	80	50.0	10.0	11.6 (1.4)	7.4 (0.5)	3.6 (0.2)
10	60	66.7	10.8	12.6 (1.2)	6.1 (1.7)	4.4 (0.4)

* Values in parentheses are standard deviations.
∓ From cooked ejectable and non-ejectable oysters.

Table 8. Effect of treatment of bottom oysters (stacked singly) with pressurized steam at different temperatures.

Temp. °C (°F)	Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
					Length	Width	Depth
110 (230)	15	100	100.0	11.6	12.4(1.6)	8.2(0.7)	4.4(0.7)
110 (230)	30	100	100.0	10.2	12.0(1.8)	7.4(0.6)	3.9(0.7)
115.6(240)	15	90	100.0	11.3	12.2(1.7)	7.6(1.0)	4.0(0.5)
115.6(240)	30	100	90.0	11.3	12.4(1.3)	7.5(0.6)	4.1(0.5)

* Values in parentheses are standard deviations.
∓ From cooked ejectable and non-ejectable oysters.

Table 9. Effect of treatment of bottom oysters at different stacking levels with pressurized steam at 110°C (230°F).

Stacking level of oysters (number)	Time (min)	Oysters gaped (%)	Meat ejectable (%)	Meat recovered∓ (%)	Mean Dimensions (cm)*		
					Length	Width	Depth
1	15	100	95.0	10.8	12.0(1.5)	6.9(0.8)	3.9(0.5)
9-10	15	100	90.0	10.50	12.2(1.1)	7.8(0.8)	4.2(0.5)
9-10	15	95	79.0	9.57	12.6(1.6)	7.3(0.6)	4.2(0.6)

* Values in parentheses are standard deviations.
∓ From cooked ejectable and non-ejectable oysters.

Table 10. Resultant losses from treatment of bottom oysters with atmospheric or pressurized steam.

Parameters	Atmospheric steam	Pressurized steam
Stacking level	single	single
Temperature	100°C (212°F)	110°C (230°F)
Time, min.	30	15
Fresh oysters, g	1599.4	1487.2
Cooked shells, g	1232.8	1114.8
Theoretical fresh meat, g	366.2	372.4
Cooked meat, g	192.1	137.3
Total weight loss, %	10.9	15.8
Meat recovered+, %	15.6	12.3
Theoretical meat loss, g	174.1	235.1
Theoretical meat loss, %	47.5	63.1
Mean length (S.D.), cm	12.7 (1.4)	12.3 (1.7)
Mean width (S.D.), cm	7.7 (0.9)	7.2 (0.8)
Mean depth (S.D.), cm	4.3 (0.7)	4.2 (0.5)

+ From cooked ejectable and non-ejectable oysters.

Table 11. Effect of short duration treatment of bottom oysters (stacked singly) with pressurized steam at 110°C (230°F).

Time (min)	Oysters gaped (%)	Meat ejectable (%)	Mean Dimensions (cm)*		
			Length	Width	Depth
1	40	50.0	12.5 (1.1)	7.3 (0.5)	4.3 (0.5)
1	50	60.0	11.2 (1.6)	7.2 (0.9)	4.1 (0.6)
1	50	70.0	11.9 (0.8)	7.3 (0.7)	3.8 (0.5)
2	50	80.0	12.2 (1.1)	7.4 (1.0)	4.0 (0.5)
2	40	50.0	13.4 (1.8)	7.5 (0.6)	4.2 (0.7)
2	60	66.7	14.0 (2.5)	7.3 (1.3)	4.0 (0.7)
4	90	66.7	12.4 (1.7)	7.9 (1.2)	4.4 (0.8)
4	80	87.5	11.2 (1.5)	7.0 (0.7)	4.2 (0.6)
4	40	75.0	12.0 (1.9)	7.3 (0.7)	4.6 (0.8)
5	100	90.0	11.8 (1.3)	7.5 (1.2)	4.4 (0.7)
5	90	88.9	11.2 (1.6)	5.5 (1.9)	4.1 (0.5)
5	100	90.0	11.6 (2.0)	7.5 (0.8)	4.1 (0.9)
10	100	80.0	11.7 (2.1)	7.1 (1.3)	4.3 (0.7)
10	100	70.0	11.5 (1.8)	7.0 (0.8)	4.5 (0.9)
10	80	87.5	11.1 (1.8)	6.8 (0.6)	4.1 (1.1)

* Values in parentheses are standard deviations.

Table 12. Influence of air storage (5°C) prior to treatment of bottom oysters with pressurized steam (110°C).*

Parameters	Fresh 0 hours	Stored 24 hours	Stored 48 hours	Stored 72 hours
Stacking level	1	1	1	1
Time treated, min.	3	3	3	3
Oysters gaped, %	30	40	65	70
Meat ejectable, %	66.7	62.5	84.6	100.0
Meat recovered†, %	16.5	18.1	18.4	16.8
Fresh oyster, g	1925.3	1923.8	2031.3	2218.3
Cooked shell, g	1159.8	1153.5	1281.4	1372.7
Theoretical fresh meat, g	765.5	770.3	749.9	845.6
Cooked meat, g	229.6	255.1	290.2	277.6
Theoretical meat loss, g	535.9	515.2	459.7	568.0
Theoretical meat loss, %	70.0	66.9	61.3	67.2
Mean length (S.D.), cm	10.1(1.4)	10.3(1.6)	10.9(1.2)	10.9(2.2)
Mean width (S.D.), cm	6.4(0.6)	6.5(0.4)	6.2(0.9)	6.6(0.9)
Mean depth (S.D.), cm	3.8(0.5)	3.7(0.5)	3.8(0.3)	3.9(0.5)

* Average values from triplicate trials.

† From cooked ejectable and non-ejectable oysters.

Table 13. Typical physical characteristics of bottom oysters subjected to experimentation.

Fresh oyster (g)	Shells (%)	Fresh meat (%)	Cavity fluids (%)	Shell thickness (mm)*	Dimensions (cm)		
					Length	Width	Depth
53.6	67.1	24.8	8.1	23	9.0	5.0	2.5
60.1	64.4	21.6	14.0	19	8.7	4.8	2.6
60.2	65.3	24.0	10.7	15	8.0	4.8	3.3
69.3	57.2	16.6	26.1	46	9.3	4.0	3.4
79.6	68.2	26.1	5.7	52	8.5	5.4	3.4
81.9	65.3	23.0	11.7	23	12.6	5.9	2.8
85.1	73.1	16.4	10.5	35	11.3	5.9	3.4
85.3	60.3	26.8	12.9	49	9.6	5.2	3.5
89.1	65.2	23.1	11.7	34	11.8	5.6	3.2
91.0	63.1	24.1	12.8	32	10.4	5.1	3.7
108.8	62.2	25.2	12.6	22	11.2	6.5	4.2
109.2	58.3	26.5	15.2	32	10.1	5.9	4.2
125.4	64.9	20.8	14.2	56	11.5	7.6	4.8
125.9	70.1	21.7	8.2	24	14.5	6.8	2.7
131.1	72.0	19.8	8.2	50	10.8	7.9	2.8
151.0	63.5	29.8	6.7	36	13.6	8.0	4.3
195.1	62.7	26.3	11.0	68	14.8	7.9	3.9
201.0	67.9	19.2	12.9	33	12.9	6.5	4.7
209.9	65.3	17.9	16.8	50	12.4	8.2	4.7
237.5	78.8	15.3	6.0	57	12.9	7.9	5.6
Mean (Standard deviation)							
117.5 (54.7)	65.7 (5.1)	22.5 (4.0)	11.8 (4.6)	37.8 (14.8)	11.2 (2.0)	6.3 (1.3)	3.7 (0.8)

* Average thickness at central location of adductor muscle attachment to left and right valves.

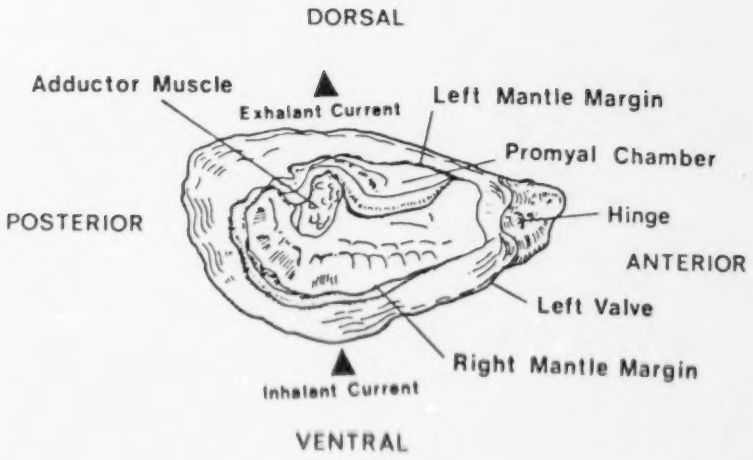

Fig. 1. Oyster, Crassostrea gigas, separated from right valve.